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RESEARCH ARTICLE

Syntaxonomic and ecological peculiarities of extra-zonal pine forests with participation of *Acer negundo* L. from the forest-steppe and steppe zones of Altai Krai (South-Eastern Siberia)

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Abstract

The syntaxonomic analysis of pine forests with *Acer negundo* occurring on fluvio-glacial sandy deposits of Altai Krai (South-East Siberia) was made based on 93 releves. It was established that *Acer negundo* takes a different phytocenotic part in 2 associations, 2 variants, and 6 no-ranked communities of 4 classes and 4 orders according to the Braun-Blanquet approach. The method of detrended correspondence analysis (DCA coordination) implemented in the DECORANA software package was used to confirm the ecological and floristic integrity of the identified vegetation units. New data on the spatial syntaxa distributions depend on the complex humidity gradient, soil fertility, and anthropogenic factors. *Acer negundo* is most abundant and common in the communities of the *Brachypodio-Betuletea pendulae* class, which are characterized by habitats with moderate moistening and greater soil fertility. In the spatial series considered, according to the soil fertility and humidity gradients, we observe an increase in *Acer negundo* in the *Vicia sylvatica – Pinus sylvestris* community and an increase in the activity of mesophytes and mesohygrophytes that are more demanding to soil fertility.

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Keywords
Pine forests, *Acer negundo*, syntaxonomy, West Siberia

Introduction

Pine psammophytic (occurring in sandy substrata) pine forests of Altai Krai are unique ecosystems of high-level conservation status (Green Book of Siberia, 1996). They represent an example of extra-zonal pine forests forming extensive ribbon-like massifs (largest in the world) in steppe and forest-steppe zones. They appeared on the ancient alluvial postglacial sands in the places of the former ancient river beds, and their massifs cross Altai Krai in the forms of four parallel ribbons running from the north-east to the south-west. The Barnaulskaya pine forest ribbon is the longest that stretches 550 km from the Ob River to the Irtysh River.

Pine forests massifs with chains of lakes and swamps scattered inside greatly influence the formation of the regional microclimate, contributing to the increase of convection processes, cloud formation, and ultimately the increase of precipitation. In recent years, the invasive species *Acer negundo* (ash-leaved maple) has been actively penetrating pine forests due to its intensive fall and overexploitation. *Acer negundo* is a biologically aggressive (invasive) species whose presence leads to significant changes in semi-natural and natural ecosystems, to the displacement of indigenous species. The invasion of this species into the destroyed natural communities (after felling, pollution by waste, destruction of the soil cover) results in essential changes in the lighting regimes and mineral properties of the soil, in the disappearance of typical for natural communities plant species. At the same time, the food supply of animals, including large ungulates, is deteriorating. In some cases, in the pine forests where the ash-leaved maple forms a well-developed layer, ground cover is almost absent. *Acer negundo* gives abundant self-sowing, occupying the young woody plantations and destroying them.

The purpose of this work was to reveal and describe those types of pine forests in which *Acer negundo* has invaded and blocked the course of natural successions.

Material and methods

The research was carried out on the territory of Altai Krai in 2019. The material was collected by the Chair of Botany, Altay State University. The analysis includes 93 complete geobotanical relevs performed by a standard procedure at the 20 x 20 m plots. Each plot was described in terms of its position in the landscape and the pine forest structure. In addition, its geographical position was specified with the use of a GPS-receiver. All collected data were stored in the TURBOVEG database (Hennekens, 1996). The classification was carried out with the ecological-floristic approach (Westhoff, van der Maarel, 1973; Dierschke, 1994) using the JUICE 7.0

software package (Tichý, 2002). The representation of syntaxonomic units was made following the Code of Phytosociological Nomenclature (Weber et al., 2000). To determine and characterize syntaxa, we used diagnostic species, including a combination of characteristic, differential, and constant species (Westhoff, van der Maarel, 1973).

The Detrended correspondence analysis (DCA-ordination) method implemented in the DECORANA software package (Hill, 1979) was used to confirm the ecological and floristic integrity of the identified vegetation units. This approach is based on the principle of 'mutual averaging', allowing the simultaneous implementation of communities and species ordination.

When classifying and performing ordination, we did not consider only the species composition in the communities but also the species cover and constancy. The cover of species was evaluated using a one-to-five scale: (+) – less than 1%; 1 – less than 5%; 2 – 6-15%; 3 – 16-25%; 4 – 26-50%; 5 – more than 50%. Geobotanical releves were summarized in phytocenological tables, and a constancy class was assigned to each species: I – less than 20%; II – 21-40%; III – 41-60%; IV – 61-80%; V – 81-100%. The taxonomic names of the vascular plants are given according to S.K. Cherepanov (1995).

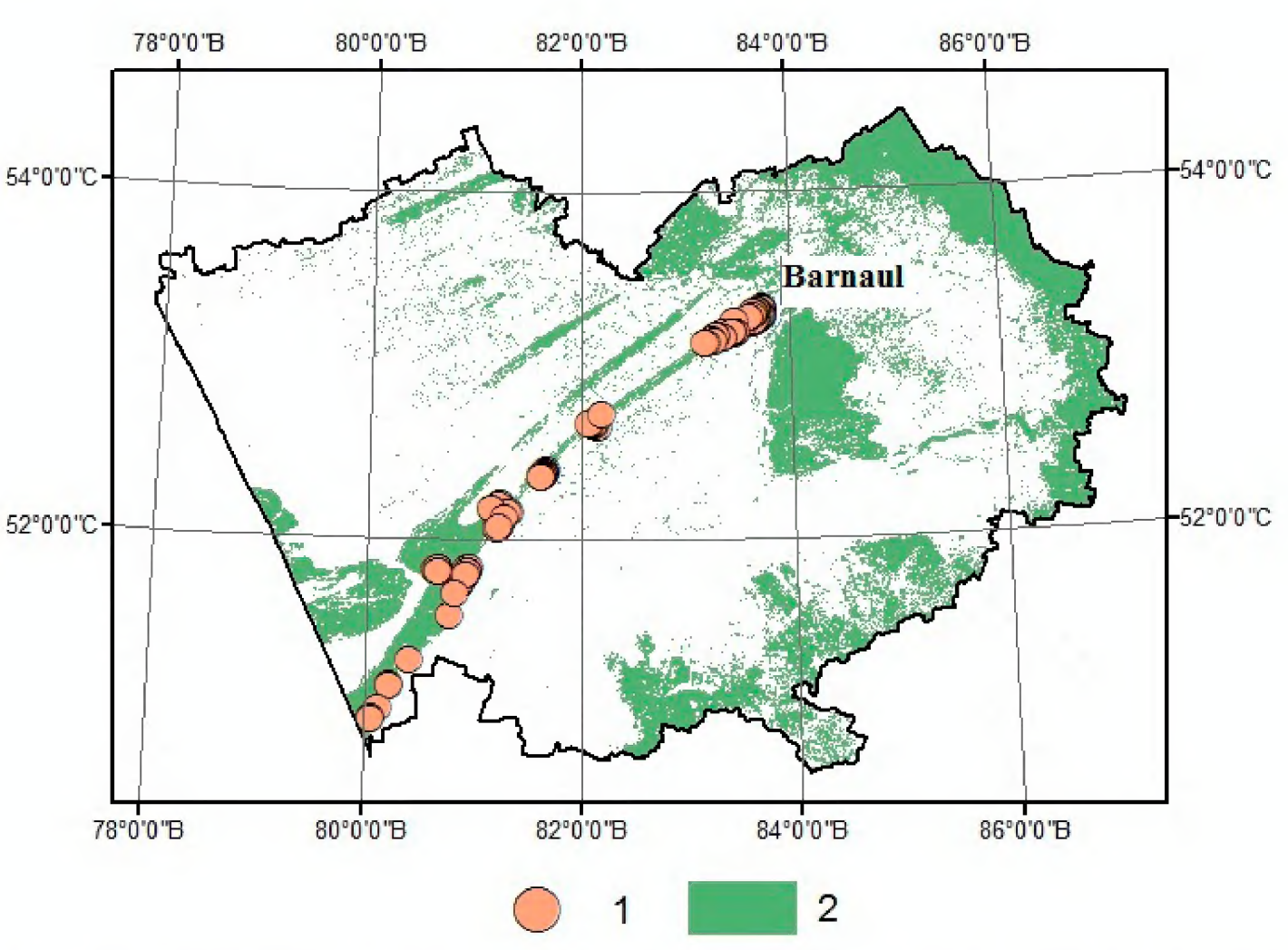

Figure 1. Map of the study area in the territory of Altai Krai: **1** – locations of releves, **2** – forests.

Results and discussion

The Braun-Blanquet classification results and the comparative syntaxonomic analysis revealed that communities with *Acer negundo* participation can be included in 4 classes, 2 associations, 2 variants, and 6 no-ranked communities.

Prodromus of Barnaulskaya ribbon pine forests with the participation of *Acer negundo*

Class *Koelerio glaucae–Pinetea* Ermakov 2020
Order *Koelerio glaucae–Pinetalia sylvestris* Ermakov 1999
Alliance *Koelerio–Pinion sylvestris* Ermakov 1999
Community *Cleistogenes squarrosae–Pinus sylvestris*
Community *Potentilla argentea–Pinus sylvestris*
Class *Vaccinio–Piceetea* Br.-Bl. in Br.-Bl. et al. 1939
Order *Pinetalia sylvestris* Oberd. 1957
Alliance *Hieracio umbellati–Pinion sylvestris* Anenkhonov et Chytry 1998
Association *Fragario vescae–Pinetum sylvestris* Lashchinskiy et al, 2018
Class *Brachypodio pinnati–Betuletea pendulae* Ermakov et al. 1991
Order *Calamagrostio epigei–Betuletalia pendulae* Korolyuk ex Ermakov et al. 2000
Alliance *Peucedano morisonii–Betulion pendulae* Ermakov 1996
Community*Vicia sylvatica–Pinus sylvestris*
Association *Equiseto hiemalis–Pinetum sylvestris caraganietosum arborescentis* Ermakov, Makunina et Maltseva ex Ermakov et al. 2000
Community *Ulmus laevis–Pinus sylvestris*
Alliance *Calamagrostio epigei–Betulion pendulae* Korolyk ex Ermakov et al. 2000
Community *Cirsium setosum–Pinus sylvestris*
Community *Lythrum virgatum–Pinus sylvestris*
Class *Alnetea glutinosae* Br.-Bl. et Tx. 1943
Order *Alnetalia glutinosae* Tx. 1937
Alliance *Alnion glutinosae* (Malcuit 1929) Muller et Gors 1958
Association *Carici omskianae–Betuletum pubescentis* Korolyuk 1993
Subassociation *Carici omskianae–Betuletum pubescentis pinetosum sylvestris* Lashchinskiy et al. 2018
Variant *Lysimachia vulgaris*
Variant *Salix cinerea*

Most of the Barnaulskaya ribbon pine forests, where *Acer negundo* was encountered, belong to the *Vaccinio–Piceetea* class and to the *Pinetalia sylvestris* order representing the boreal oligotrophic pine forests of Northern Eurasia. Currently, the order includes three alliances (Ermakov, Morozova, 2011), the representative in the studied area is the *Hieracio umbellati–Pinion sylvestris* alliance comprising oligotrophic and oligomesotrophic mesophytic and xeromesophytic pine forests in the

south of the forest and forest-steppe zones of Siberia. Within the alliance, we identified one *Fragario vescae–Pinetum sylvestris* association, where *Acer negundo* was encountered.

Association *Fragario vescae–Pinetum sylvestris*, Lashchinskiy et al, 2018

Diagnostic species: *Pinus sylvestris*, *Fragaria vesca*, *Thalictrum simplex*, *Lathyrus vernus*, *Orthilia secunda*.

Forests of this association are found on light loamy soils with a high content of silt. The cover of the tree layer is 50% and it is subdivided into two layers. The first sublayer is 25 m high and is made up of pine (*Pinus sylvestris*), the second (20 m) is made up of pine and birch (*Betula pendula*). The average age of the pine is 60, the average diameter of the trunk is 32 cm, the maximum one is 45 cm. The average age of the birch is 40, the average diameter of the trunk is 16 cm, and the maximum is 23 cm. The total cover of the shrub layer is 3-5%. It is represented by *Sorbus sibirica*, *Acer negundo*, *Padus avium*, *Malus baccata*, *Viburnum opulus*, and *Rosa majalis*.

The average cover of the grass layer is 35%. The species richness varies from 17 to 25 plant species per 100 m^2. The main dominants are *Fragaria vesca*, *Calamagrostis epigeios*, *Poa angustifolia*, *Iris ruthenica*, *Carex macroura*.

The grass layer consists of two sublayers. The first sublayer (50-60 cm high) is formed by *Calamagrostis epigeios*, *Poa angustifolia*, *Carex macroura*, *Polygonatum odoratum*, and *Trifolium lucanicum*. The second sublayer (15 cm high) is formed by *Fragaria vesca*, *Iris ruthenica*, *Orthilia secunda*, *Viola hirta*, *Antennaria dioica*. The moss layer characterised by a total cover of up to 10% comprises *Dicranum polysetum* and *Pleurozium schreberi*.

Occasional occurrence of *Acer negundo* was observed in arid pine forest communities with significant participation of xeric steppe and meadow-steppe species, many of them facultative or obligate psammophytes. Such forests, found in the southern part of the pine forest ribbons, belong to the European-West Siberian *Koelerio–Pinetea* class, the *Koelerio glaucae–Pinetalia sylvestris* order, and the *Koelerio-Pinion sylvestris* alliance. They were classified as two no-ranked communities: *Cleistogenes squarrosae–Pinus sylvestris* and *Potentilla argentea–Pinus sylvestris*.

Cleistogenes squarrosae–Pinus sylvestris community

Diagnostic species: *Pinus sylvestris*, *Koeleria glauca*, *Cleistogenes squarrosa*, *Artemisia commutata*.

A 60-70% cover characterizes the tree layer and it is composed of two sublayers formed by pine (*Pinus sylvestris*). The higher sublayer is 20 m, the lower one is 13-15 m. The average age of the pine is 45, the average diameter of the trunks is 18 cm, and the maximum is equal to 30 cm. The cover of the shrub layer is 1-3%/ It consists of *Crataegus sanguinea* (1% cover), *Ribes aureum* (1% cover), *Acer negundo* (3% cover).

The cover of the grass layer is 10 - 35%, its height reaches 70 cm, the diversity of species is 20 species per 100 m2. The primary dominants are *Cleistogenes squarrosa*, *Artemisia commutata*, and *Koeleria glauca*. The grass layer consists of 3 sub-layers. The first sublayer (70 cm high) is formed by *Artemisia commutata*, *A. sieversiana*, *Bromopsis inermis*. The second (30-35 cm high) is formed by *Koeleria glauca*, *Potentilla canescens*, *Dracocephalum nutans*, and *Conyza canadensis*. The third sublayer (15-20 cm high) features *Cleistogenes squarrosa*.

***Potentilla argentea–Pinus sylvestris* community**

Diagnostic species: *Pinus sylvestris*, *Populus tremula*, *Vicia cracca*, *Calamagrostis pseudophragmites*, *Thyselium palustre*.

The tree layer is characterized by 30% cover. The average age of pine is 70, the average diameter of the trunks is 33 cm (the maximum one is 45 cm). The average age of the aspen is 50-60, the average diameter of the trunks is 20 cm (the maximum is 25 cm). The first sublayer of the tree layer is formed by pine (*Pinus sylvestris*) of 30 m height. The second one is formed by aspen (*Populus tremula*) of 20 m high. The cover of the shrub layer is 1-3%. It is formed by *Caragana arborescens* (1.5 m high) and *Acer negundo*.

The cover of the grass layer reaches 40%, and the species richness is 23 species per 100 m^2. The main dominants are *Calamagrostis pseudophragmites* and *Vicia cracca*. The grass layer consists of two sublayers. The first (100-120 cm high) is formed by tall grasses – *Calamagrostis pseudophragmites*, *Bromopsis inermis*, *Thyselium palustre*, and *Bromopsis inermis*. The second (30-40 cm high) is formed by *Vicia cracca*, *Galium verum*, *Iris ruthenica*, *Rumex acetosa*, and *Viola rupestris*.

Acer negundo was observed in the hemoboreal birch-pine grass forests of the *Brachypodio pinnati-Betuletea pendulae* class, which are widespread in the Barnaulskaya pine forest ribbon in drained habitats with richer sandy loamy and clay loamy soils. An association and four communities without rank described within this class were assigned to the *Calamagrostio epigei–Betulion pendulae* alliance. It represents the primary mesophilous and hygro-mesophilous birch and pine forests of the West Siberian Lowlands in medium and light chernozem-like alkaline, loamy solodic soils.

***Equiseto hiemalis–Pinetum sylvestris caraganietosum arborescentis* association**

The diagnostic species: *Pinus sylvestris*, *Fragaria vesca*, *Carex macroura*, *Rubus idaeus*, *Pulmonaria mollis*, *Pteridium aquilinum*, *Caragana arborescens*, *Equisetum hyemale*.

Mesophilous psammophilous birch-pine grass forests in moderately humid oligotrophic and oligomesotrophic habitats on ancient fluvioglacial sand deposits and high terraces of large river valleys (Ob, Irtysh, and Tobol) (Ermakov et al., 1997; Ermakov, 2003). The tree layer of the community has covered 50% and consists of two

sub-layers. The first sublayer (20-25 m high) is formed by the pine (*Pinus sylvestris*) and by the birch (*Betula pendula*), and the second one (18-20 m high) is formed by the elm (*Ulmus laevis*) and the ash-leaved maple (*Acer negundo*). The average age of pine (*Pinus sylvestris*) is 70, the average diameter is 28 cm, the maximum is 60 cm. The cover of the shrub layer is 5-7%. It includes *Padus avium*, *Caragana arborescens*, *Acer negundo*, *Sorbus sibirica*, *Rhamnus cathartica*, *Salix caprea*, *Crataegus sanguinea* (Fig. 2). The cover of the grass layer reaches 25%, its height being up to 70 cm, the species richness is 21 species per 100 m^2. The primary dominants are *Carex macroura*, *Pulmonaria mollis*, *Equisetum hyemale*, *E. sylvaticum*, *Calamagrostis epigeios*, *Carex macroura*, *Brachypodium pinnatum*. The grass layer consists of three sublayers. The first sublayer (80 cm high) is formed by *Brachypodium pinnatum*, *Calamagrostis epigeios*, *Peucedanum morisonii*, and *Lathyrus vernus*. The second sublayer (30-35 cm high) is formed by *Pulmonaria mollis*, *Kadenia dubia*, *Carex macroura*, and *Rubus saxatilis*. The third sublayer (15-20 cm high) includes *Vaccinium myrtillus*, *Vaccinium vitis–idaea*, *Fragaria viridis*, *Maianthemum bifolium*, *Orthilia secunda*.

The moss layer is not well developed (except for the most oligotrophic habitats) and is represented by *Pleurozium schreberi*, *Dicranum polysetum*, and *Diphasiastrum complanatum* with a total cover of up to 10–15%.

The association is close to the 'pine grass-shrub forest' community described by Lapshina (1985) on the terraces of the Pyshma, Tuva, Tobol, Irtysh, and Ob rivers in the forest-steppe zone of the West Siberian plain.

Figure 2. *Equiseto hiemalis-Pinetum sylvestris caraganietosum arborescentis* association. Ermakov, Makunina et Maltseva ex Ermakov et al. 2000.

Vicia sylvatica–Pinus sylvestris community (Altai Krai, surroundings of Barnaul area, Yuzhny settlement)

Diagnostic species: *Pinus sylvestris*, *Pteridium aquilinum*, *Vicia sylvatica*, *Vaccinium myrtillus*, *Dactylis glomerata*, *Trifolium pratense*.

The tree layer has 30% cover and is composed of two sub-layers. The first sublayer (30 m high) is formed by *Pinus sylvestris*, the second one (20 m high) is formed by *Betula pendula*. The average age of the pine is 60, the average diameter of its trunks is 30 cm, the maximum is 47 cm. The average age of the birch is 40, the average age diameter of its trunks is 15 cm, the maximum is 25 cm (Fig. 3).

The total cover of the shrub layer is 20%. It is formed by *Sorbus sibirica*, *Acer negundo*, and *Viburnum opulus*.

The cover of the grass layer reaches 50%. The species richness is 18 species per 100 m^2. The main dominants are *Pteridium aquilinum*, *Polygonatum odoratum*, *Vaccinium myrtillus*, and *Pulmonaria mollis*. The grass layer is subdivided into three sublayers. The first sublayer (80 cm high) is formed by *Dactylis glomerata*, *Artemisia vulgaris*. The second sublayer (50 cm high) is formed by *Impatiens parviflora*, *Vicia sylvatica*, *V. unijuga*, *Pteridium aquilinum*, *Polygonatum odoratum*. The third sublayer (15-20 cm high) is formed by *Fragaria viridis*, *Vaccinium myrtillus*, and *Pulmonaria mollis*.

These communities bear numerous traces of anthropogenic impact, such as tracing ruts, fire pits, and traces of selective felling.

Figure 3. *Vicia sylvatica-Pinus sylvestris* community

Ulmus laevis–Pinus sylvestris community (Altai Krai, Aleyskiy district, surroundings of Kostin Log village area)

Diagnostic species: *Pinus sylvestris*, *Ulmus laevis*, *Sorbus sibirica*, *Lupinaster pentaphyllus*, *Pteridium aquilinum*, *Impatiens parviflora*, *Vicia sylvatica*, *Vaccinium myrtillus*, *Polygonatum odoratum*.

The tree layer has 40% cover and is subdivided into two sub-layers. The first sublayer (25 m high) is formed by the pine (*Pinus sylvestris*), the second one (10 m high) is formed by the pine and the elm (*Ulmus laevis*). The average age of the pine is 60, the average diameter of its trunks is 25 cm, the maximum is 43 cm. The average age of the elm (*Ulmus laevis*) is 15 (Fig. 4).

The cover of the shrub layer is 20%. It includes *Acer negundo*, *Padus avium*, *Humulus lupulus*, *Caragana arborescens*, and *Rubus idaeus*.

The cover of the grass layer reaches 40%, the species richness is 25 species per 100 m^2. The main dominants are *Calamagrostis epigeios*, *Fragaria viridis*. The grass layer consists of three sublayers. The first sublayer (70 cm high) is formed by *Poa pratensis*, *Calamagrostis epigeios*, *Brachypodium sylvaticum*, and *Artemisia pontica*. The second sublayer (30 cm high) is formed by *Galium verum*, *Agrimonia pilosa*, *Thalictrum simplex*, *Origanum vulgare*. The third sub-layer (15 cm high) is formed by *Fragaria viridis*, and *Ranunculus polyanthemos*.

Cirsium setosum–Pinus sylvestris community (Altai Krai, Aleyskiy district, surroundings of Kostin Log village area)

Diagnostic species: *Pinus sylvestris*, *Bromopsis inermis*, *Rubus saxatilis*, *Calamagrostis epigeios*, *Angelica palustris*, *Cirsium setosum*, *Fragaria viridis*.

The tree layer of the community has covered 30% and is subdivided into two sublayers. The first sublayer (25 m high) is formed by pine (*Pinus sylvestris*), the second (15 m) is formed by birch (*Betula pendula*) and aspen (*Populus tremula*). The average age of the pine is 80, the average diameter of its trunks is 30 cm, the maximum is 40 cm. The cover of the shrub layer reaches 10 % and is composed of *Acer negundo* (cover is 7 %) and *Caragana arborescens* (cover is 3 %).

The grass layer cover reaches 60 %, the height is up to 140 cm, and the species richness is 17 per 100 m^2. The main dominants are *Calamagrostis epigeios*, *Fragaria viridis*, *Cirsium setosum*. The grass layer consists of three sublayers. The first sublayer (140 cm high) is formed by *Bromopsis inermis*, *Calamagrostis epigeios*, *Cirsium helenioides*, *C. setosum*, *Angelica palustris*. The second sublayer (30-35 cm high) is formed by *Polygonatum odoratum*, *Equisetum hyemale*, *Lathyrus pratensis*. The third sublayer (15-20 cm high) features *Fragaria viridis*, *Epipactis helleborine*, *Urtica urens*, *Rubus saxatilis*, *Epilobium palustre*.

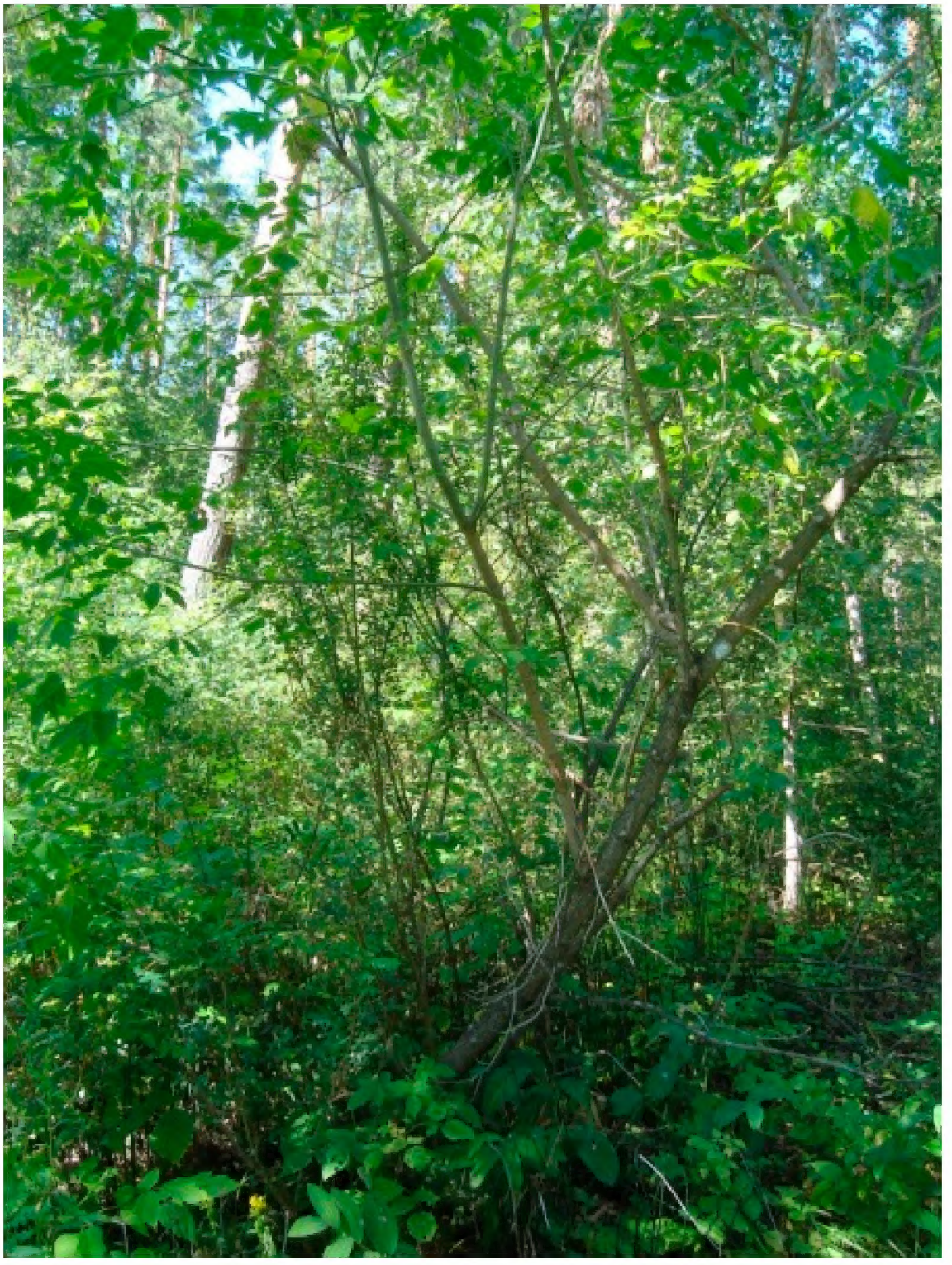

Figure 4. *Ulmus laevis-Pinus sylvestris* community.

***Lythrum virgatum–Pinus sylvestris* community (Altai krai, Aleyskiy district, surroundings of Kostin Log village area)**

Diagnostic species: *Pinus sylvestris*, *Rubus saxatilis*, *Brachypodium pinnatum*, *Peucedanum morisonii*, *Equisetum hyemale*, *Lythrum virgatum*.

The tree layer of the community has 20% cover and is subdivided into two sublayers. The first sublayer (25 m high) is formed by the pine (*Pinus sylvestris*), the second (15 m) is formed by the birch (*Betula pendula*). The average age of the pine is 80, the average diameter of its trunks is 40 cm, the maximum is 60 cm. The shrub layer has 30% cover and is formed by *Acer negundo*, *Caragana arborescens*, *Rosa majalis*, *Rubus idaeus*, *Salix caprea*.

The cover of the grass layer reaches 40%, the height is up to 100 cm, and the species richness is 23 species per 100 m^2. The main dominant is *Brachypodium pinnatum*. The grass layer consists of two sublayers. The first sublayer (100 cm high) is formed by *Lythrum virgatum*, *Cirsium setosum*, and generative shoots of *Brachypodium pinnatum*, *Poa palustris*. The second sublayer (50 cm high) is formed by P*eucedanum morisonii*, *Geum aleppicum*, *Lactuca tatarica*, *Polygonatum odoratum*, *Equisetum hyemale*, *Vicia sepium*.

In addition to the communities described above, *Acer negundo* is found in bogged forests of the *Alnetea glutinosae* class, confined to habitats with increased fertility and excessive stagnant moisture. Their structure and floristic composition are close to the communities of the *Caricio omskianae–Betuletum pubescentis* association described from the northern forest-steppe of the Baraba Lowland (Korolyuk, 1993). The bogged pine forests of the Barnaulskaya ribbon differ from the typical communities of this association by the constant participation of *Pinus sylvestris* in the undergrowth and species such as *Urtica dioica*, *Phragmites australis*, *Orthilia secunda*, and *Calamagrostis epigeios* in the grass layer. The community is a particular variant of the *Caricio mskianae–Betuletum pubescentis pinetosum sylvestris* subassociation (Lashchinsky et al., 2018) occupying extensive shallow depressions with peat horizons in the soil (15-60 cm thick).

***Lysimachia vulgaris variant* (Altaiskii krai, Novichikhinsky district, surrounding area of the Melnikovo village)**

Diagnostic species: *Pinus sylvestris*, *Orthilia secunda*, *Lysimachia vulgaris*, *Carex riparia*, *Caragana arborescens*, *Poa angustifolia*.

The tree layer has 50% cover and is subdivided into two sublayers. The first sublayer (25 m high) is formed by pine (*Pinus sylvestris*), and the second one (13-15 m) is formed by birch (*Betula pendula*). The average age of the pine is 50, the average diameter of the trunks is 40 cm, the maximum is 60 cm. The shrub layer cover reaches 30 % and is formed by *Acer negundo*, *Caragana arborescens*, *Rosa majalis*.

The grass layer cover reaches 45%, the height is up to 100 cm and the species richness is 18 species per 100 m^2. The primary dominants are *Carex riparia* and *Poa angustifolia*. The grass layer consists of two sublayers. The first sublayer (100 cm high) is formed by *Carex riparia*, *Filipendula ulmaria*, *Solidago virgaurea*, L*ysimachia vulgaris*, *Asparagus officinalis*. The second sublayer (50 cm high) is formed by *Lathyrus pratensis*, *Galium boreale*, *Rubus caesius*, *Vicia sepium*, *Artemisia pontica*.

***Salix cinerea* variant (Altai Krai, Novichikhinsky district, surroundings of Melnikovo village area)**

Diagnostic species: *Pinus sylvestris*, *Carex riparia*, *Ribes nigrum*, *Salix cinerea*, *Phragmites australis*, *Rorippa sylvestris*.

The tree layer has 20% cover and is subdivided into two sub-layers. The first sublayer (25 m high) is formed by the pine (*Pinus sylvestris*), and the second one (13-15 m) is formed by the birch (*Betula pendula*). The average age of the pine is 50, the average diameter of the trunks is 40 cm, and the maximum one is 50 cm. The projective cover reaches 20% and is formed by *Acer negundo*, *Caragana arborescens*, *Padus avium*, *Salix cinerea*, *Ribes nigrum*, *Rosa majalis* (Fig. 5).

The grass layer cover reaches 60%, the height is up to 130 cm, and the species richness is 23 per 100 m^2. The primary dominants are *Carex riparia*, *Phragmites australis*, and *Poa angustifolia*. The grass layer consists of two sublayers. The first sublayer (130 cm high) is formed by *Phragmites australis*, *Poa angustifolia*, *Cirsium setosum*, *Thalictrum simplex*, *Lathyrus pisiformis*. The second sublayer (60 cm high) is formed by *Carex riparia*, *Geum aleppicum*, *Galium boreale*, *Rorippa sylvestris*, *Mentha arvensis*, *Heracleum dissectum*.

Acer negundo exhibits different participation indices in the described forest communities depending on phytocenotic and local environmental conditions. In the *Cleistogenes squarrosae–Pinus sylvestris* and *Potentilla argentea–Pinus sylvestris communities*, *Acer negundo* is occasionally represented in the tree layer. Its cover is no more than 3%, the maximum height is 10 m, it is no more than 20 years old, and the average diameter of the trunks is no more than 6 cm. The representation of the maple in the shrub layer reaches up to 4 m high and 5% of the cover. Seedlings are not observed. Shallow depressions are the most favorable type of microrelief for their growth and development in these communities. In open spaces in good illumination conditions, the maple is represented by a multistemmed life form (usually 2-3-trunked).

Figure 5. *Salix cinerea-Pinus sylvestris* community.

Acer negundo is best developed in the *Fragario vescae–Pinetum sylvestris* association. It is recorded with a maximum cover of 5% in the tree layer (up to 4 adult specimens on the site). Their age does not exceed 20-25; the maximum height is 12 m, the trunk diameter is 6 cm. When considering reproduction, it is necessary to mention occasional young growth (up to 10 pcs. on the registration site with an average height of 35 cm) and seedlings (up to 6 pcs.). In the shrub layer, the maple cover reaches 10%. With a well-developed shrub layer and under greater dimming conditions, it acquires a monocormic or creeping form.

In the association of *Equiseto hiemalis–Pinetum sylvestris caraganietosum arborescentis* and the *Vicia sylvatica–Pinus sylvestris* community, *Acer negundo* occurs with the highest cover values (80-90%) and here it occasionally forms monodominant communities with the almost complete absence of ground layer. Numerous traces of anthropogenic impact characterize such communities. The most favorable moisture conditions and optimal illumination promote various forms of maple life (from monocormic to multitrunked and creeping types). The total number of adult maple specimens in the discount area in monodominant communities is 12; the age is 20-25. The maximum height of the trees is 15 m, and the diameter of the trunks does not exceed 18 cm. The maple is more frequent in the *Ulmus laevis–Pinus sylvestris*, *Cirsium setosum–Pinus sylvestris*, *Lythrum virgatum–Pinus sylvestris* communities in the shrub layer (coverage of up to 7%) than in the tree layer. The shrub layer with a total cover of 30% is sometimes not the most favorable habitat for maple; here, an almost complete absence of seedlings and young growth is observed.

In the *Alnetea glutinosae* class of bogged forests (*Lysimachia vulgaris* and *Salix cinerea variants*), *Acer negundo* is reduced compared to previous communities, as habitats are confined to increased fertility and excessive stagnant moisture, which is not favorable for maple growth. We registered adult specimens up to 7 m tall that lost their vigor (felled or partially flooded in the depressions). In these communities, young maple growth (up to 13 specimens, up to 1 m tall) is recorded. Adult specimens encountered in the tree layer do not exceed 7 m in height with a maximum trunk diameter of 8 cm.

The DCA coordination of the entire set of geobotanical releves was carried out to determine the pine forest communities' environmental differentiations with *Acer negundo* (Fig. 6).

The central axis 1 is well interpreted as a soil humidity factor since the extreme left position on axis 1 was occupied by the *Potentilla argentea–Pinus sylvestris* community of dry pine forests with the predominance of xerophilous and mesoxerophilous species. The extreme right position on axis 1 is occupied by the *Vicia sylvatica–Pinus sylvestris* community, characterized by greater participation of mesophilous and hygromesophilous plant species.

Axis 2 of the DCA coordination is interpreted as the gradient of the soil fertility factor. The *Cirsium setosum–Pinus sylvestris* community, the *Lysimachia vulgaris* variant, and the *Salix cinerea* variant are founded predominantly on loamy soils and are located in the upper part of axis 2. The communities dominantly associated with

sandy substrates (*Equiseto hiemalis–Pinetum sylvestris caraganietosum arborescentis*) occupy the lower part of axis 2.

When analyzing the proportion of *Acer negundo*, it can be mentioned that it avoids poor and dry soils, preferring moderately rich and rich soils. This is proved by the distribution of the communities in the DCA diagram (Fig. 6). If soil aeration deteriorates due to swamping, *Acer negundo* is registered in the *Cirsium setosum–Pinus sylvestris* and *Lythrum virgatum–Pinus sylvestris* communities. The dune-oligotrophic conditions are less favorable for the growth of ash-leaved maples and are represented by the *Fragario vescae–Pinetum sylvestris* communities.

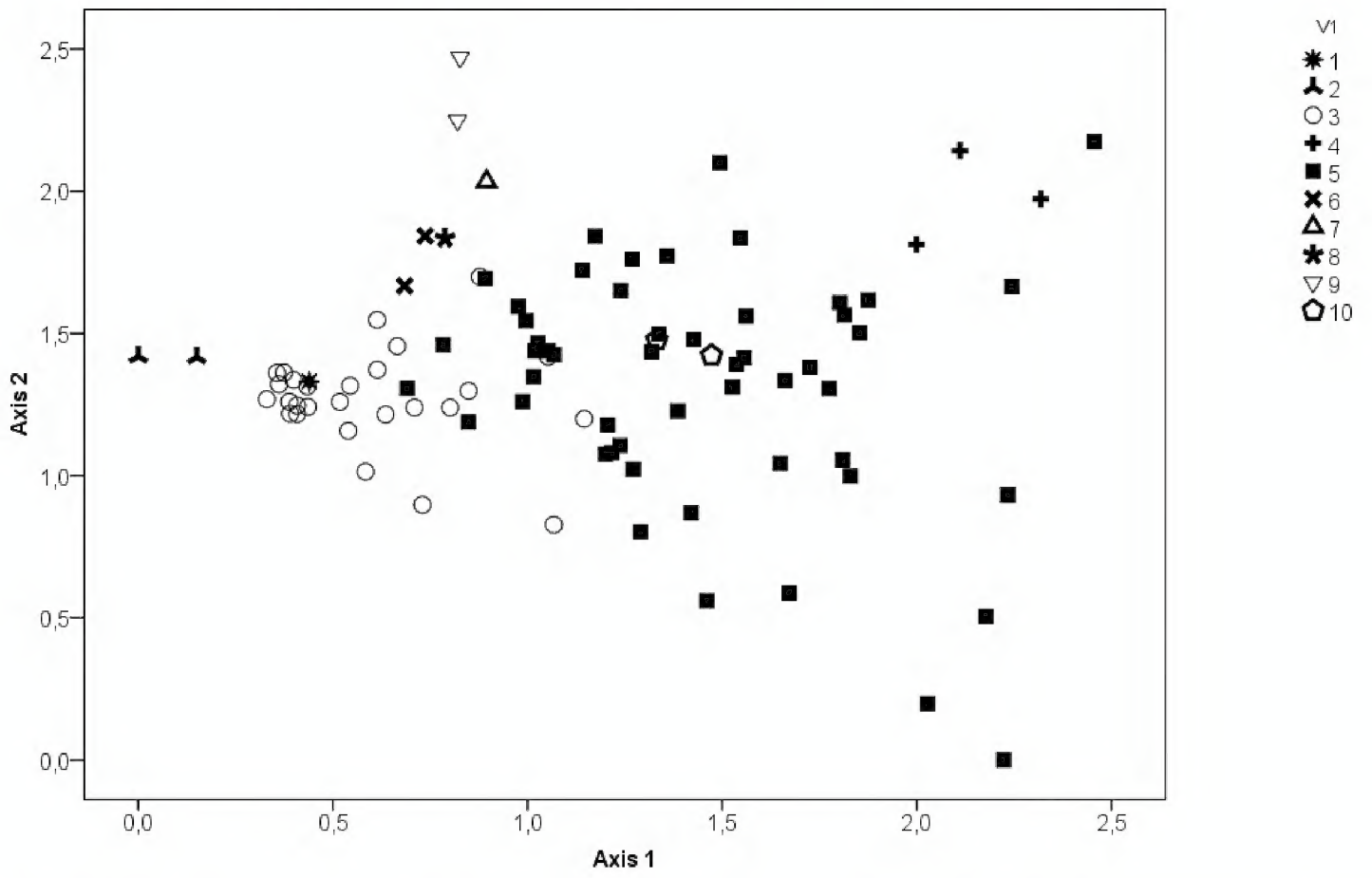

Figure 6. Distribution of forest communities with the participation of *Acer negundo* along the axes 1 and 2 DCA. **1.** *Cleistogenes squarrosae–Pinus sylvestris* community; **2.** *Potentilla argentea–Pinus sylvestris* community; **3.** F*ragario vescae–Pinetum sylvestris* association; **4.** *Vicia sylvatica–Pinus sylvestris* community; **5.** *Equiseto hiemalis–Pinetum sylvestris caraganietosum arborescentis* association; **6.** *Ulmus laevis–Pinus sylvestris* community; **7.** *Lysimachia vulgaris* variant; **8.** *Salix cinerea* variant; **9.** *Cirsium setosum–Pinus sylvestris* community; **10.** *Lythrum virgatum–Pinus sylvestris* community.

Conclusion

Thus, the syntaxonomic diversity of pine forests with the participation of *Acer negundo* is represented by two associations, two variants, and six no-ranked communities belonging to four classes of vegetation.

According to the DCA ordination results, all the allocated syntaxa are floristically and ecologically well distributed in the space of the leading factors of moisture

supply and soil fertility. At the same time, the complex and diverse dune microrelief of the sandy deposits redistributes the effects of the leading environmental factors and creates a wide range of habitats within each ecological topographic series of plant communities, which leads to a high degree of tessellation of the vegetation cover. As a result, the *Brachypodio–Betuletea pendulae* class's mesic forests are combined with the bogged forests of *Alnetea glutinosae* in the same micro-relief.

The study results allow us to conclude that *Acer negundo* occasionally occurs in communities of the *Koelerio–Pinetea* class representing the driest pine forests with the participation of steppe and meadow-steppe species, many of which are facultative or obligatory psammophytes. *Acer negundo* is most abundant and frequent in the communities of the *Brachypodio–Betuletea pendulae* class, which are characterized by habitats with moderate moistening and greater soil fertility.

In the considered spatial series, according to the gradients of the soil fertility and humidity, we observe an increase in the *Acer negundo* participation in the *Vicia sylvatica–Pinus sylvestris* community and an increase in the activity of mesophytes and mesohygrophytes that are more demanding to the soil fertility. In such conditions, the maple can occasionally form monospecies communities, with the cover reaching 90%. Only occasional adult maple specimens were recorded in the most humid conditions and in habitats with increased soil fertility, along the bottoms of vast depressions occupied by the *Salix cinerea* and *Lysimachia vulgaris* variants.

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